Coastal Engineering Technical Note

APPLICATION OF A BROADBAND ACOUSTIC DOPPLER CURRENT PROFILER FOR TIDAL CURRENT MEASUREMENTS AT COASTAL INLETS

PURPOSE:

The purpose of this Technical Note is to introduce BroadBand Acoustic Doppler Current Profiler (BBADCP) technology and to illustrate its use during a recent field investigation to measure tidal currents at Shinnecock and Moriches Inlets, Long Island, New York. Discussions are directed towards the operational principles, functional characteristics and capability of this state-of-the-art instrument.

BACKGROUND:

Measurement of the current flow is an essential step toward understanding hydrodynamic and sediment transport processes at coastal inlets. This is usually accomplished by conducting field measurements in which current meters are deployed at pre-determined locations and depths within the inlet system. Current meters used for this purpose are generally either duct-impeller type meters or electro-magnetic type meters. They are usually deployed from a moored survey boat/ship and lowered to desired depths, and are often inefficient and time consuming. The BBADCP overcomes limitations of these traditional systems.

The BBADCP, manufactured and commercially available only from RD Instruments (RD Instruments, 1992), is a multiple-beam Doppler remote profiling system that can measure vertical profiles of 3-axis velocities and acoustic backscattering strength by transmitting short acoustic pulses and processing their reflections from small particles in the water. The BBADCP was used during a field investigation sponsored by the New York District conducted at Moriches and Shinnecock Inlets on 21-23 July 1992. The purpose of the field investigation was to study the overall current patterns and the effect of currents upon the development and characteristics of scour holes which abut the west jetty at each inlet. These scour holes, which reach 20 m in depth and occupy an area of 4,500 m^2 at the 15-m depth contour, undermine the jetties, thus resulting in their failure at the seaward ends.

The BBADCP current measurement transects were run at each inlet in the vicinity of scour holes both across the inlet and out the inlet seaward from the tip of the jetties. Additional transects were run to measure overall tidal current patterns at landward portions of the inlet, and across both the east and west back bay channels. The BBADCP was able to collect tidal current vector data

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across the inlet along specified transects at a much faster rate and with great improvement in spatial resolution. During the 1992 field study, 50 to 64 profiles were measured during one tidal cycle compared to approximately 15 to 20 profiles (about 1 to 4 vertical measurements per profile) conducted during a 1991 field study at these same inlets using an electromagnetic current meter.

OPERATION PRINCIPLE:

Acoustic current measuring devices operate on the principle that a pulse of sound energy (commonly referred to as a ping) transmitted in the water will be scattered by particles suspended in the water. The sound energy that is reflected back to the receiver will have experienced a Doppler shift that is proportional to the velocity of the water, assuming that the particles are moving with the same velocity as the water in which they are suspended.

The BBADCP used for this experiment has four transducers each of which transmits a beam of acoustical energy pointed in a different direction. Figure 1 depicts a typical beam orientation for a ship-mounted ADCP. Two beams point parallel to the centerline of the ship (one pointed fore and the other aft) and the other two beams are pointed in opposite directions perpendicular to the centerline of the ship. All beams have a 30-deg angle with respect to the vertical. A pulse of acoustical energy is simultaneously transmitted along each of the four beams. Following, the returned scattered signal is measured at the receiver.

Different time intervals of the returned signal can be associated with a particular range of depth in the water column (a bin) if the speed of sound in water is known. The Doppler shift of the reflected signal is calculated for each bin and is used to estimate the average velocity of the water along the axis of the beam in the bin. From these four along-the-beam velocity components the north-south, east-west, and vertical components of water velocity in each bin can be determined. Only three beams are necessary for this calculation, and the fourth beam enables the system to make an estimate of the data quality. This quality estimate allows the system to assess the validity of the assumption of horizontal homogeneity of the water velocity over the area covered by the four beams.

Until recently, ADCP's have used incoherent signal processing techniques to measure the Doppler shift. This type of ADCP, known as a narrow band ADCP, measures the average Doppler shift over a bin for each ping. A system employing this type of signal processing is capable of measuring velocity profiles over great depths, but has large bin sizes and long averaging times that are typically only useful in deep-water situations.

Recent technological advances have led to the development of the BBADCP which uses coherent signal processing techniques and coded acoustical pulses for improved measuring capabilities. Coherent processing techniques determine the Doppler shift by measuring the variation in the phase of the signal from ping to ping for each bin (Brumley et al. 1991). The BBADCP achieves a finer spatial resolution (smaller bin size) with a higher degree of precision (lower standard deviation) over a shorter averaging time as compared with the narrow band ADCP. These improvements make the BBADCP well suited for applications in shallow coastal and inland waters.

The BBADCP is manufactured in several different frequency ranges (75 kHz, 150 kHz, 300 kHz, 600 Hz, and 2400 kHz). Higher frequencies give finer spatial resolution and increased precision but at reduced ranges (Table 1).

System frequency (kHz)	2400	1200	600	300	150	75
Profiling depth (m)						
High power mode	-	-	-	160	300	500
Low power mode	5	20	60	130	230	410
Start of 1st cell (m below water surface)	0.3	0.5	1	2	4	8
Precision (cm/s)						
Bin size = 0.12 m	4	-	-	-	-	-
Bin size = 0.25 m	3	10	-	-	-	-
Bin size = 0.5 m	2	4	10	-	-	-
Bin size = 1.0 m	1	2	4	20	-	-
Bin size - 2.0 m	-	1	2	4	10	-
Bin size = 4.0 m	-	-	1	2	4	15
Bin size = 8.0 m	-	-	-	1	2	5
Bin size = 16.0 m	-	-	-	-	1	3

Table 1. Comparison of BBADCP frequency with profiling range and bin size (modified after RD Instruments 1992).

SETUP FOR FIELD OPERATION:

One of the advantages of the BBADCP is the relatively simple deployment and operation of the system. The system consists of the instrument itself (an aluminum pressure housing approximately 80 cm in length and 22 cm in diameter with acoustic transducers mounted on one end; favorable results have also been obtained by mounting only the pressure sensors overboard without the use of the pressure housing (Kraus (ed.), 1991)), a small deck box for connecting the instrument to the computer, a computer (a 386 or faster IBM-PC type), and connector cables.

For the deployment at Shinnecock and Moriches Inlets the instrument was strapped to an aluminum pipe which was mounted on the side of a survey boat (length of 7.5 m) (Figure 2). The transducer head of the BBADCP was at a depth of approximately 80 cm. A communication cable was connected to the top on the instrument by a water tight connector and led to the deck box which was stationed in the cabin of the boat. The deck box was in turn connected to a laptop computer which ran the data collection software. The entire system was powered by a small portable 120-volt generator on the boat.

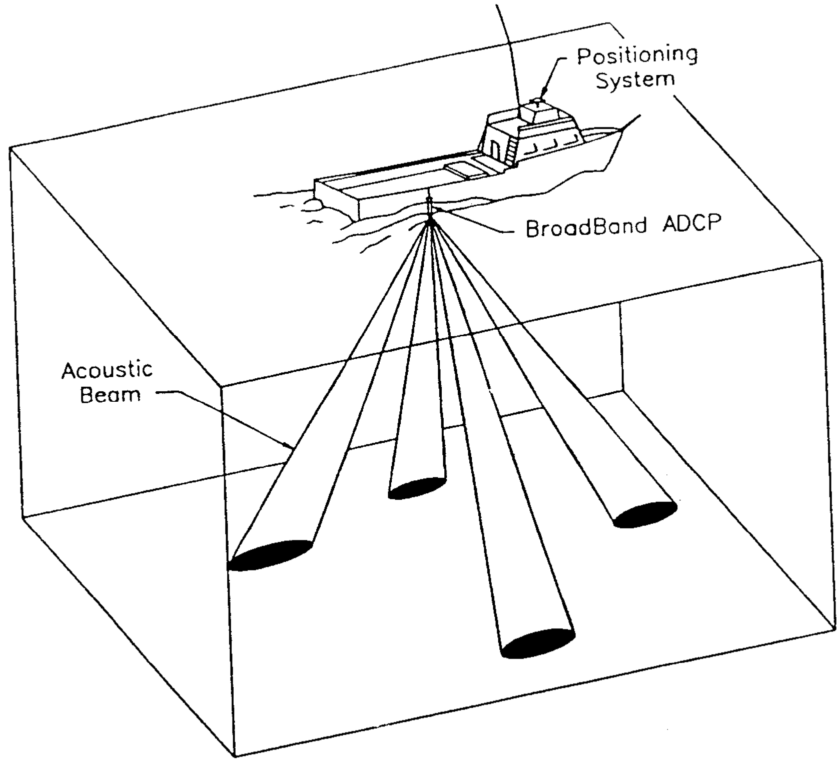

Figure 1. Typical beam orientation of BroadBand ADCP.

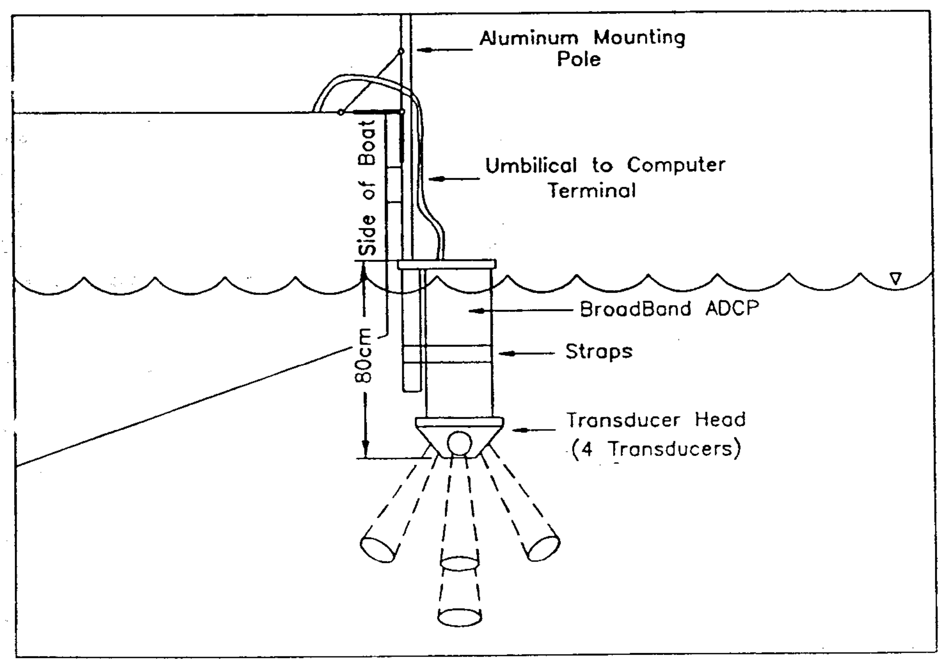

Figure 2. Typical BroadBand ADCP deployment as used at Shinnecock and Moriches Inlets.

The software running the instrument, which is available from RD Instruments, allows for operator input of a variety of parameters making it possible to customize the data collection to different locations and conditions. The operator can adjust the bin size, depth range, pings per ensemble (average time), navigational method, and other parameters pertaining to the data collection and storage.

Although the software is set up to interface with different navigational systems (GPS, LORAN-C, Microfix) and store these data along with the velocity data, the BBADCP built-in dead reckoning navigational capability was used for this deployment. This navigational system uses the compass contained in the instrument and ship velocity determined from bottom tracking to calculate a relative ship motion.

Data were collected by making transects across the inlets, starting and stopping approximately 5 m from the jetty on either side. The collection of data closer to the jetties is ineffectual as the jetties would begin to interfere with the beam patterns of the transducers. Boat speed averaged approximately 0.75 m/s. At the seaward side of the jetty, seas of 0.3 - 1.0 m were encountered. Associated instantaneous wave orbital velocities affecting currents could not be measured as a 7-second sampling interval was utilized. The use of a smaller sampling interval would compensate less for boat motion and result in a higher standard deviation of data.

The data were stored on the hard drive of the computer and later down-loaded to floppy disk. The data could then be reviewed using software provided by the BBADCP manufacturers or transformed into data files for use in other data processing programs.

SAMPLES OF CURRENT DATA:

Recorded current data at Shinnecock and Moriches Inlets were analyzed to determine the north-south, east-west, and vertical components of currents through the entire water column at each transect location. Additional analyses of current data included the degree of backscatter (suspended matter), resultant vectors of currents at depths throughout the water column, tabular format listing current velocity in two directions, and discharge across the transect. Vessel heading, speed, pitch and roll, and transect length and time were also calculated.

Figures 3 and 4 illustrate typical current profiles across Shinnecock Inlet entrance between the jetties obtained with the BBADCP. The horizontal axis plots time, and the vertical axis plots depth (m). Current velocity (cm/s) and direction are indicated by the scale to the right where "positive" currents are directed toward the north or east denoted by the red colors, and "negative" currents are directed toward the south or west. Figures 3 and 4 illustrate the north/south and the east/west components, respectively, of the currents at Shinnecock Inlet during the mid-flood tide stage. Currents to the north and east (of up to 110 cm/s) flood the inlet. Note that currents to the south (of up to 60 cm/s) exit the inlet on the sides of the inlet adjacent to the jetties during the flood phase of the tide (currents to the north).

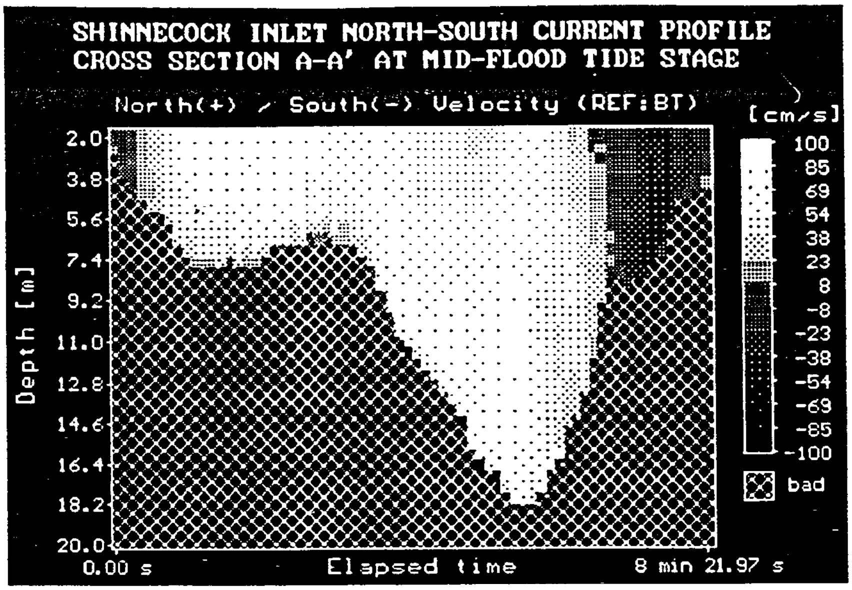

Figure 3. North/south components of Shinnecock Inlet currents during the mid-flood tide stage.

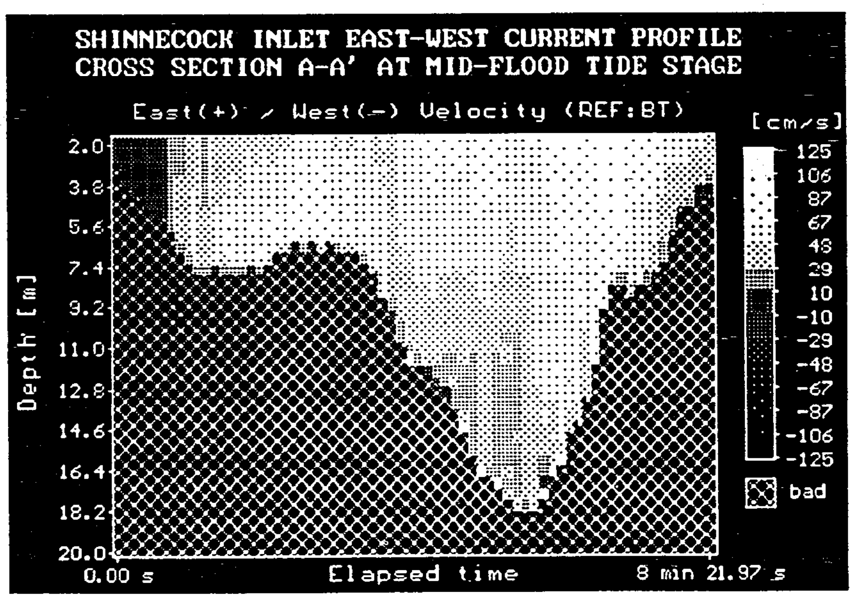

Figure 4. East/west components of Shinnecock Inlet currents during the mid-flood tide stage.

(Note: Color versions of these figures are available.)

ADDITIONAL INFORMATION:

For additional information on the application and availability of the BBADCP at coastal inlets, contact Dr. Yen-Hsi Chu, (601) 634-2067, J. Bailey Smith, (601) 634-3043, or Paul T. Puckette, (601) 634-2336 of the Coastal Engineering Research Center.

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